Automation of Stage preparation activities of LVM 3 Launch Vehicle during Vehicle Assembly

S.Balaji T.Jerry Alexander

***Abstract* -This paper deals with automation of stage preparation activities of LVM3 (Launch Vehicle Mark - III) during Vehicle Assembly. The LVM 3 vehicle consists of three stages, one cryo stage, one liquid stage and two solid stages. The stage preparation activities include the charging of POGO gas bottles, leak check of liquid stage, DM water filling etc. The stage preparation activities are automated by using Programmable logic controller system (Hot standby controller with TMRIO) using PLC software Unity Pro IDE and SCADA system (redundant server client architecture) using Vijeo Citect Package both are provided by Schneider electric.**

***Index Terms* — Helium Gas Bottle Charging, Hot Stand-by Programmable Logic Controller, POGO-CSM Gas Bottle Charging, SCADA (Supervisory Control and Data Acquisition).**

I. INTRODUCTION

LVM 3 or Launch Vehicle Mark 3 is a next generation heavy launch Vehicle being developed by Indian Space Research Organization (ISRO). It is capable of placing 4 ton class spacecraft to Geo-Synchronous transfer orbit and also suitable for X (man) Mission. The vehicle has three stages [2]

1. S200 (two Solid boosters each of 207 tons of HTPB Propellant).
2. L110 (N204 & UH25 based propellants of 110 tons).
3. C25 (Cryo propellant of 25 tons).

Fig.1. out -lines the new control system realized for performing the VAB related L-110 and S200 stage activities. The system can access data of all the field elements, execute control operations of field elements through automatic or manual mode operations remotely.

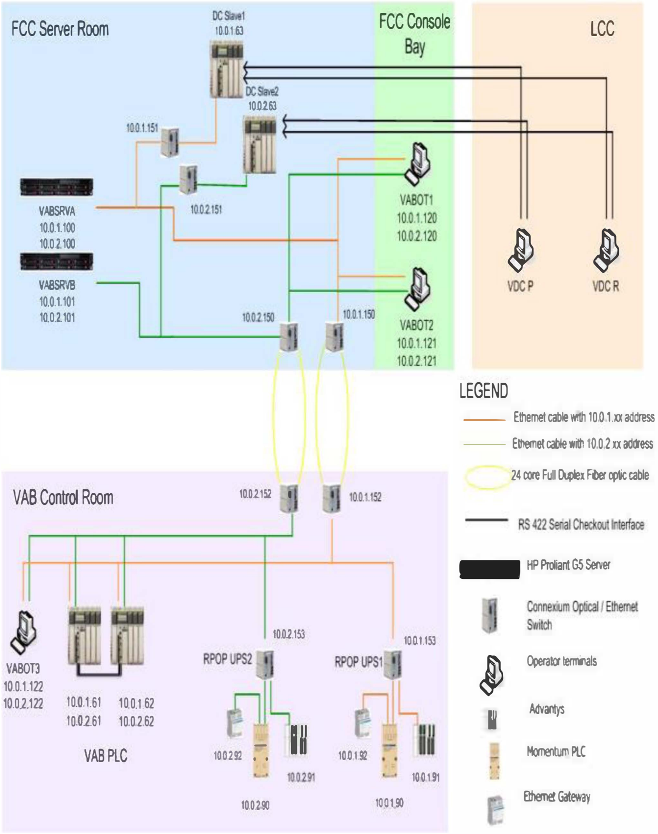

Fig.1. Overall System Configuration

The pre-launch related remote operation as per process requirement is to be performed in a safe, accurate and precise manner and in a pre – determined sequence. The Hot Stand-by Programmable Logic Controller [4] with triple modular redundant I/O's are at the VAB (Vehicle Assembly Building) control room and the servers along with operator stations are positioned at filling control centre. The I/O cards are interfaced to the field elements through the Instrumentation Junction Box (IJB). The program for the acquisition of data from sensors, executing the process algorithms, commanding the field elements is executed in the

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PLC with cyclic mode. The VAB Control System is connected with ring topology using Fiber optic Cables with network redundancy. The server requests the data from PLC and sends the data to operator station via switch and the Ethernet link. The stage is acquired by VAB PLC through RS422 serial link from Vehicle Director Console at checkout system.

The major stage preparation activities includes

1. Stage qualification by performing leak checks of liquid stage or tank which includes L110 Helium Gas Bottle Charging, L110 POGO-CSM Gas Bottle Charging and L110 Propellant Tank Pressurization.
2. FNC tank qualification for solid stage for providing actuator control of pitch, yaw and roll control of vehicle which requires S200 FNC Charging.
3. DM water filling into the liquid stage which acts as a coolant and is required to run the liquid engines. [1]

II. DESIGN CONSIDERATIONS

A. Specifications for POGO & CSM charging

Nitrogen	R Grade N2
Bottle Volume (CSM)	35.0 lit
Bottle Volume for POGO	12.0 lit
Nominal bottle pressure	$210.0^{+5.0}$ bar Atmospheric (a)
Phase I Charging	Up to 125.0 bar(a)
Charge rate (max)	4.0 bar/min

B. Specifications for Helium charging

Helium	Type I, Grade A/4.5 grade
No. of Bottles	9 Nos
Bottle Volume	117.5 lit/bottle
Nominal bottle pressure	$335.0^{+10.0}$ bar(a)
Phase I Charging	Up to 125.0 bar(a)
Charge rate (max)	4.0 bar/min
Gas temperature max. limit	50^0C
Skin temperature max. limit	45^0C
Gas temperature min. limit	10^0C
Skin temperature min. limit	10^0C

C. Specifications for gas charging of S-200 FNC

Volume of Nitrogen gas tank	0.880 m^3
Volume of Oil tank	0.225 m^3
Working Pressure	280.0 bar(a)
Operating fluid in gas tank	N2 R-grade
Charge Rate for gas tank	2 bar/minute.
The FNC gas tanks need to be charged to 280 bar in two phases. First Phase up to 150 bar in manual/remote mode and second phase from 150 bar to 280 bar in remote mode.	

D. Specifications for pressurization of propellant and water tanks

For tank pressurization and depressurization 5 bar GN2 supply is required for the following operations:

- Waiting phase pressurization of tanks to 1.3 ±0.1 bar (a)
- Pressure hold checks at 2.5±0.1 bar
- Pre fill pressurization of tanks to 2.5 bar for N tank and 2.0 bar for U tank.

Tank	Pre fill pressure	Volume (m^3)
N tank	2.5±0.1 bar	50.53
U tank	2.5±0.1 bar	50.53
Water tank	2.5±0.1 bar	1.775

III. PROCESS ALGORITHM

1. L110 Helium Gas Bottle Charging

A. Input data entities

- Stage analog data, ground analog data and ground digital data.

B. Algorithm or formula of process

- Acquire ground data from field sensors and stage data from DC_LCC.
- Check for initiation of L110 helium gas bottle charging.
- Check initial conditions for gas bottle charging
- Wait for chief authorization for charging.
- Check line pressure and correct the line pressures to required value.
- Start gas bottle charging by opening the required valves and ensure their open status.
- Monitor gas bottle parameters continuously with necessary actions.
- Close all the related valves after target is reached and ensure the close status of stage commands.

C. Affected data entities

- The Stage Data used in Gas Process Algorithms
- Variables communicating to and from PLC and SCADA [3]

Here the algorithm for L110 POGO-CSM Gas Bottle Charging and L110 Propellant Tank Pressurization will be same as L110 Helium Gas Bottle Charging except with the field elements, Charging rate and SCADA mimic will be different

2. S200 FNC Charging

A. Input data entities

- Stage analog data, ground analog data and ground digital data.

B. Algorithm or formula of process

- Acquire ground data from field sensors and stage data from DC_LCC.
- Check for initiation of S200 FNC charging.
- Check initial conditions for gas bottle charging
- Wait for chief authorization for charging.
- Check line pressure and correct the line pressures to required value.
- Start gas bottle charging by opening the required valves and ensure their open status.
- Monitor gas bottle parameters continuously with necessary actions.
- Close all the related valves after target is reached and ensure the close status of stage commands.

C. Affected data entities

- The stage data used in Gas Process Algorithms
- Variables communicating to and from PLC and SCADA

Flowchart shows the complete operations performed for qualification of the tanks. The process elements like Electro Pneumatic (EP) valves, Orifice, Pressure transmitters, Pressure switches, and Temperature transmitters are used for entire filling process as per the design considerations given. These process elements are interfaced with remote I/O modules like analog input module which receives stage pressure from pressure transmitters, analog output module for commanding control values, digital input modules for getting Pressure switches status and digital output module to command values.

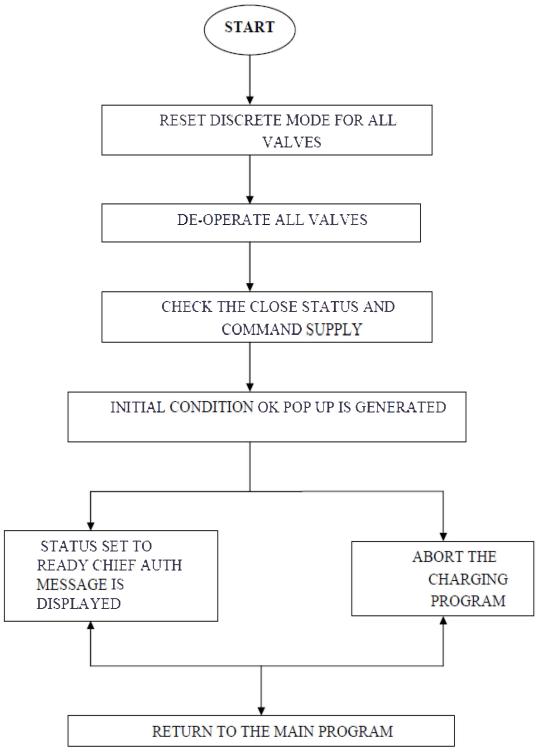
START
RESET DISCRETE MODE FOR ALL VALVES
DE-OPERATE ALL VALVES
CHECK THE CLOSE STATUS AND COMMAND SUPPLY
INITIAL CONDITION OK POP UP IS GENERATED
STATUS SET TO READY CHIEF AUTH MESSAGE IS DISPLAYED
ABORT THE CHARGING PROGRAM
RETURN TO THE MAIN PROGRAM

Fig.2.Initial Condition Check

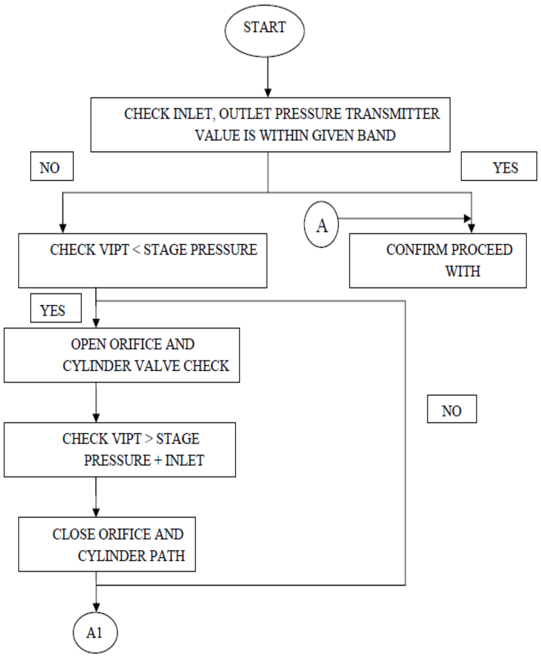
START
CHECK INLET, OUTLET PRESSURE TRANSMITTER VALUE IS WITHIN GIVEN BAND
NO
YES
A
CHECK VIPT < STAGE PRESSURE
CONFIRM PROCEED WITH
YES
OPEN ORIFICE AND CYLINDER VALVE CHECK
NO
CHECK VIPT > STAGE PRESSURE + INLET
CLOSE ORIFICE AND CYLINDER PATH
A1

Fig.3. Line readiness for the charging-1

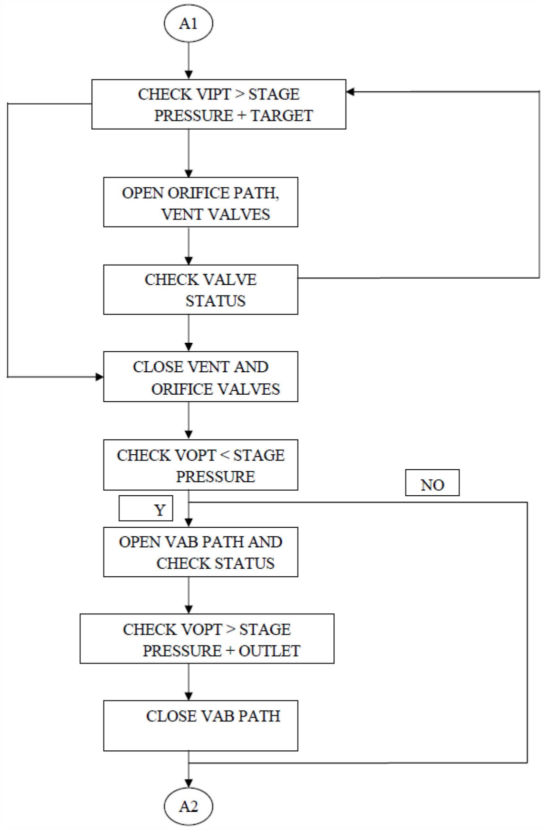
A1
CHECK VIPT > STAGE PRESSURE + TARGET
OPEN ORIFICE PATH, VENT VALVES
CHECK VALVE STATUS
CLOSE VENT AND ORIFICE VALVES
CHECK VOPT < STAGE PRESSURE
NO
Y
OPEN VAB PATH AND CHECK STATUS
CHECK VOPT > STAGE PRESSURE + OUTLET
CLOSE VAB PATH
A2

Fig.4. Line readiness for the charging 2

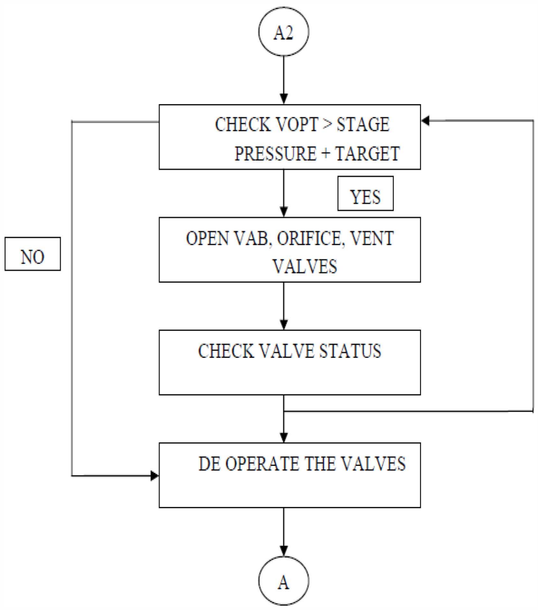
A2
CHECK VOPT > STAGE PRESSURE + TARGET
YES
NO
OPEN VAB, ORIFICE, VENT VALVES
CHECK VALVE STATUS
DE OPERATE THE VALVES
A

Fig.5. Line readiness for the charging 3

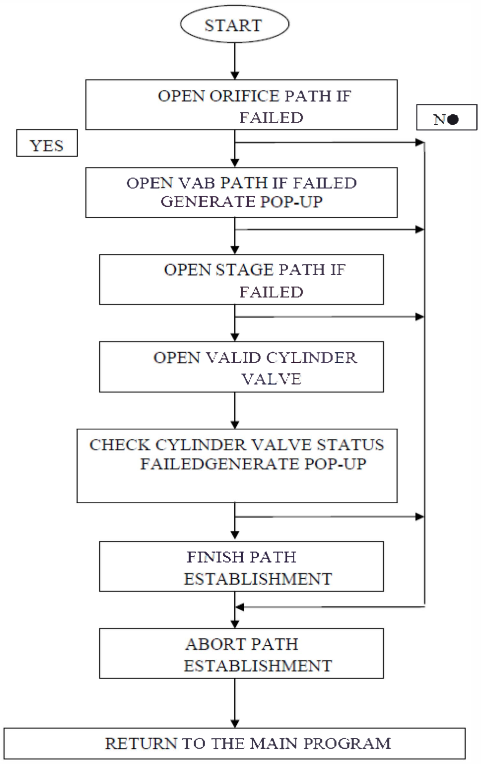
START
OPEN ORIFICE PATH IF FAILED
YES
NO
OPEN VAB PATH IF FAILED GENERATE POP-UP
OPEN STAGE PATH IF FAILED
OPEN VALID CYLINDER VALVE
CHECK CYLINDER VALVE STATUS FAILEDGENERATE POP-UP
FINISH PATH ESTABLISHMENT
ABORT PATH ESTABLISHMENT
RETURN TO THE MAIN PROGRAM

Fig.6. Path Establishment for Charging

IV. RESULTS

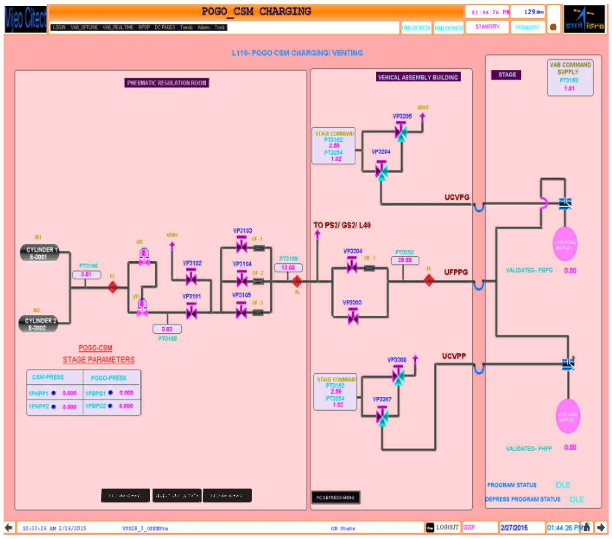
POGO_CSM CHARGING
L110-POGO CSM CHARGING/ VENTING
PNEUMATIC REGULATION ROOM
VEHICAL ASSEMBLY BUILDING
STAGE
UCVPG
UFPPG
UCVPP
TO PS2/ GS2/ L40
POGO-CSM STAGE PARAMETERS

Fig.10. POGO & CSM charging

Fig.10. shows the POGO & CSM charging. The mimic is designed as per the algorithm and flowcharts. To start charging all initial conditions like values, sensor status is checked. If the conditions are satisfied then it is required to wait for authorization. The phase I charging is done upto 125.0 bar (a) and the phase II charging is done upto 210.0$^{+5.0}$ bar (a) with maximum charge rate of 4.0 bar/min.

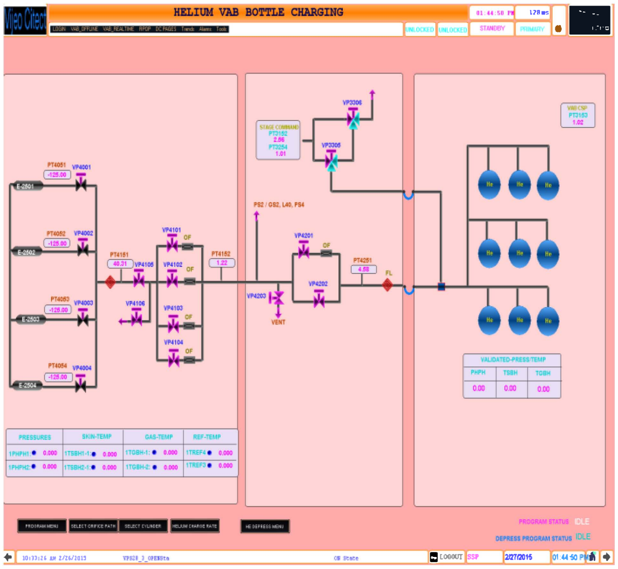

Fig.11. Helium charging

Fig.11. shows the helium charging, the mimic is designed as per the algorithm and flowcharts. To start charging all initial conditions like EP valves and sensor statuses are checked. If conditions are met then after waiting for authorization the phase I charging is done upto 125.0 bar (a) and the phase II charging is done upto $335.0^{+10.0}$ bar (a) with maximum charge rate of 4.0bar/min.

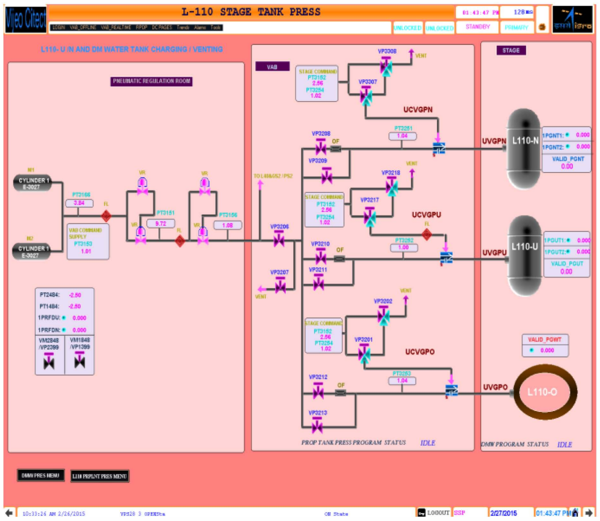

Fig.12. Stage tank pressurization

Fig.12. shows the pressurization of U & N tank, the mimic is designed as per the algorithm and flowcharts. To start charging all initial conditions like EP valves, sensor status are checked and if it meets the requirement then wait for the authorization. Waiting phase pressurization of tanks to 1.3 ±0.1 bar (a), pressure hold checks at 2.5±0.1 bar and Pre fill pressurization of tanks to 2.5 bar for N tank and 2.0 bar for U tank

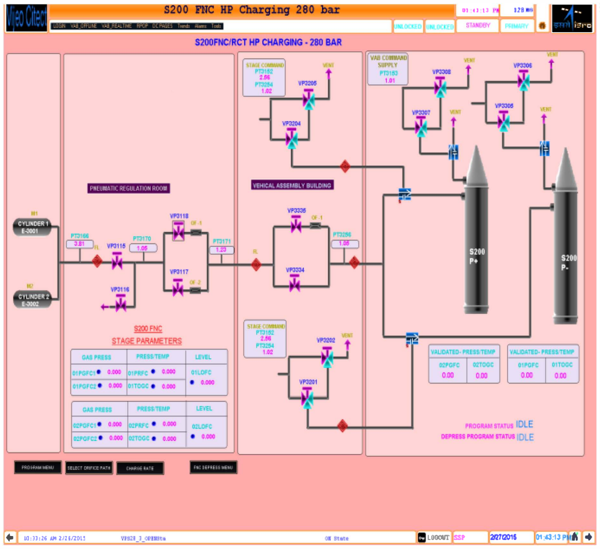
S200 FNC HP Charging 280 bar
Vijeo Citect
S200FNC/RCT HP CHARGING - 280 BAR
PNEUMATIC REGULATION ROOM
VEHICAL ASSEMBLY BUILDING
S200 FNC
STAGE PARAMETERS
S200 P+
S200 P-
PROGRAM STATUS IDLE
DEPRESS PROGRAM STATUS IDLE

Fig.13. FNC charging

Fig.13. depicts the FNC Nitrogen gas tank charging and the mimic is designed as per the algorithm and flowcharts. To start charging all initial conditions like EP valves, sensor status is checked .If conditions are satisfied then wait for the proper authorization.

The FNC gas tanks need to be charged to 280 bar in two phases. First Phase up to 150 bar in manual/remote mode and second phase from 150 bar to 280 bar in remote mode.

V. CONCLUSION

Automated system is developed using PLC & SCADA for remotely operation of stage preparation activities of LVM 3 launch vehicle. The program coding is compiled and simulated in control system lab with all type of possible iterations and all the results are satisfactory. This automated system is qualified for stage servicing activities of S200 & L110 stages of LVM 3 launch vehicle.

VI. ACKNOWLEDGMENT

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VII. REFERENCES

[1] P.Swathi, “Development of process automation system for servicing of ISRO satellite launch vehicles during vehicle assembly” International Conference on Computer Science and Mechanical Engineering, pp 44-47,August 2014.

[2] Somanath Sreedhara Panicker, ISRO, “GSLV MK-III Development Challenges and present status”, 61st International Astronautical Congress, 2010.

[3] PCC APROL-User Manual for SCADA Package (Proprietary).

[4] Start Up Guide for Unity Pro Installing an Application - User Manual for PLC (Proprietary).